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A Review of the Solar Energy Situation in Rwanda and Uganda

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ABSTRACT

This paper reviews the solar energy development and future in Rwanda and Uganda. In these two countries, solar energy sector plays an important role in supporting socio-economic development. The paper examines the development of solar energy market in both Uganda and Rwanda since their beginnings in the 1980s. The current size, structure and efficiency of solar PV systems show their future development. It was found that the price of solar PV systems will continue to decline due to the rising of oil price, PV technology development, the prolonged support from international donors and helpful framework conditions provided by governments such as subsidies, the import duty and VAT exemptions, and feed in-tariff. In the paper, it is shown that the solar market of Rwanda is the second after Uganda for on-grid solar uses in East Africa. Currently, solar PV modules used to produce electricity of 8.5 MW to the national grid while more than 177,000 solar home systems are installed in different parts of Rwanda. Further, Uganda has the largest solar power plant in East Africa within installed capacity of 10 MW whereas; more than 30,000 solar PV systems had been installed in different areas in Uganda. Finally, the challenges and opportunities facing Rwanda and Uganda in development of solar energy are presented in this study.

1. INTRODUCTION

Africa, probably more than any other continent, faces the double challenges of improving the living conditions of its population by sharply increasing energy access, while at the same time developing its energy sector in a way that is sustainable (Janosch O., 2011). East Africa is one of five regions of Africa that faces these challenges due to the quickly growing populations and rising prosperity that lead to increased energy demand. The East African Community traditionally was composed by three states (Kenya, Uganda and Tanzania) with a combined population of over 120 million people in 2014 (Othieno H. O. and Awange J. L., 2016). In June 2007, two new members, Rwanda and Burundi joined the Community (Grant E., 2014). The last country to join East African Community (EAC) was South Sudan, completely becoming a member of the community in April 2016(Institute for Security Studies (ISS), 2016).

There is a crucial need to move from existing fossil fuel based energy systems to one based on renewable resources to decrease reliance on depleting reserves of fossil fuels (Vivek P. and Tarlochan K., 2014). There are many reasons to decrease consumption of reserves of fossil fuels. Among these main reasons, one is the increasing carbon dioxide (CO_2) emissions which cause climate change and global warming, and the other is the increasing consumption of non-renewable energy sources (coal, oil and natural gas) (Vukica J. and Helena M., 2014; Uwisengeyimana J.de D. *et al.*, 2016). Although Africa has small access to electricity, it is a very beautiful place of good potentiality of renewable energy resources such as solar energy, geothermal energy, hydro and wind energy (Uwisengeyimana J.de D. *et al.*, 2016). Africa has an exceptional solar resource that can be used for electricity generation and for thermal applications. The desert regions of North Africa and some parts of Southern and Eastern Africa enjoy particularly long sunny days with a high intensity of irradiation. There are also other regions such as Sahelian and Tropical are also feature strong solar irradiation. However, solar energy can be utilised at various levels, making it suitable from the household and community to industrial and national levels (IRENA, 2015).

This paper is structured as follows: After this introductory section 1, solar energy review in Uganda is presented in Section 2. Solar energy review in Rwanda is presented in section 3. Section 4 of the paper presents the challenges and opportunities facing solar energy sector in Rwanda and Uganda. Finally, the conclusions are in section 5.

2. Uganda

Uganda is a landlocked country in east-central Africa and is located beside Lake Victoria with altitude of 900 to 1,500 metres above sea level that makes its climate cooler than might be expected in a country which lies across the equator within temperatures range from 15-32°C (World Vision Australia, 2010). Uganda has a total area of 241,550.7 square kilometres and its Population was 34.6 million persons (censuses, 2014). Total installed capacity of electricity was 895.5 MW in 2015 (Uganda Bureau of Statisitic, 2016). Uganda has a limited access to electricity of 21% (14% at the national level and 7% in rural areas) (African Development Bank, 2015).

2.1. Solar energy market in Uganda

The PV market in Uganda started to be developed from the early 1980s, and, as in Tanzania and Kenya, it was initially managed mainly by government and international donors through NGOs projects, mainly was used for lighting and vaccine refrigeration in health centres (GTZ, 2007). Uganda has a good level of insolation within the mean solar radiation of 5.1 kWh/m^2 per day), on a horizontal surface. This level is favorable for the application of a number of solar technologies. An estimated 200 MW of potential electrical capacity are available in Uganda. Today, solar energy is mainly used for off-grid electrification to power rural communities, as well as for lighting, phones and radio charging, solar cooking, and providing water heating and power to public buildings (Adeyemi K.O. and Asere A.A., 2014).

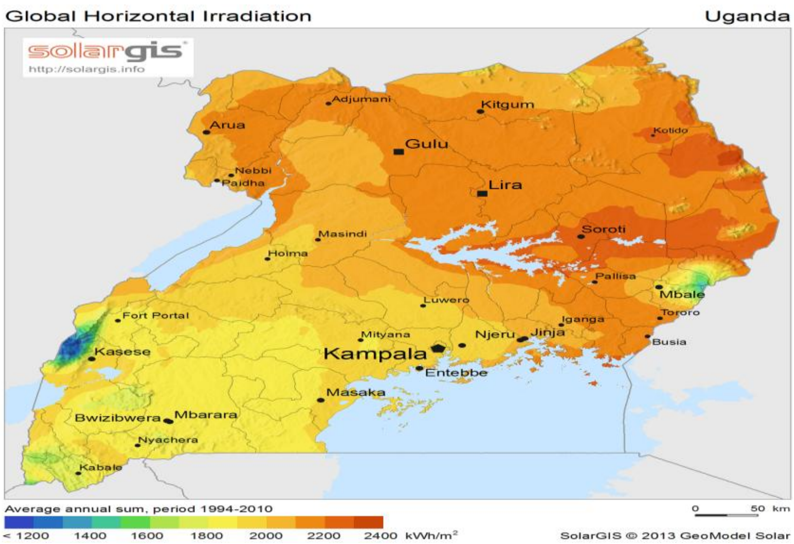

Figure 1: Global horizontal irradiation map of Uganda

Currently, in Uganda, there are two larger projects in line. The government of Uganda wants to build 500 MW of utility-scale solar power with Ergon Solair, a Taiwanese-US partnership. This project will be divided into four parks of 125 MW each. The construction of the first phase was planned to start in 2014 with an expected completion by October 2016. Additionally, Ergon Solair also signed a 2,000 MW agreement with the East African Chamber of Commerce, Industry and Agriculture (EACCIA) owned by a Kenyan, Tanzanian and Ugandan chamber (Parnell J., 2013; Solar Media Limited, 2013).

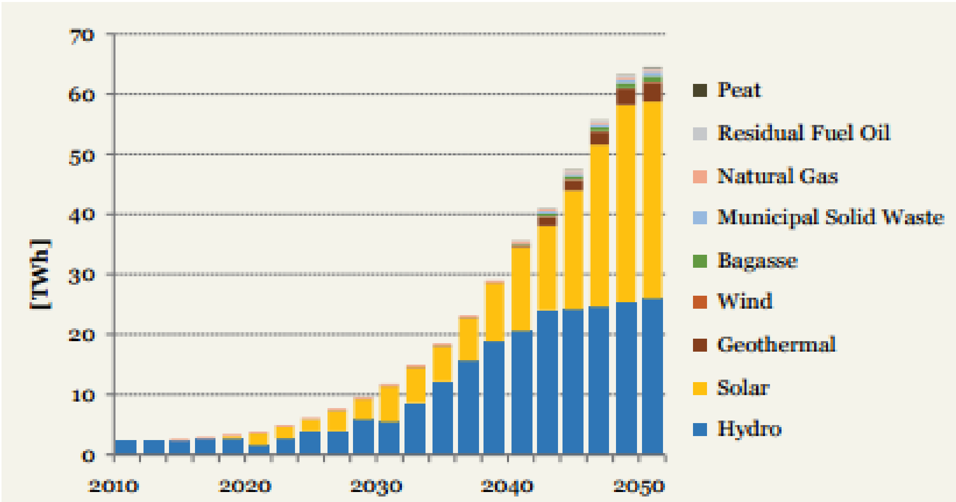

Figure 2: Electricity supply and specification of electricity mix – renewable energy scenario (Gustavsson M. *et al.*, 2015)

As shown in Fig. 2, Uganda has abundant renewable energy potential. These are biomass, hydro, solar and geothermal resources. This high potential can make Uganda at position as a regional leader with an energy system based on renewable sources by 2050 where solar energy will be most usefully to generate electricity.

2.1.1. Off-grid systems

In Uganda, there are many companies and NGOs which are promoting rural electrification, especially for off-grid areas. The Foundation Rural Energy Services (FRES) is one of those companies of off-grid players in Uganda, a non-profit organization that supports companies in rural areas in different African countries by supplying them solar PV systems. The companies install solar home systems mainly for commercial and household use and charges a fixed monthly fee based on the amount of the kWh consumed. Fenix International is also solar technology company with a daily payment of $0.15. In fact, rural households are able to afford this price because it is cheaper compared to electricity bill; people have to pay $160 for solar home system in 3 years. By considering the average salary of employee per day in rural areas of Uganda of $2, Fenix offers a significant opportunity for rural Ugandans to get electricity (Solarplaza, 2017). In 2012, solar home systems had been installed in 420 small commercial, 1,700 institutions and 5,600 households of Uganda through programmes initiated by Rural Electrification Agency (REA) of Uganda and other international donor agencies (MEMD (2012b), 2012). These figures can be contrasted with the counter sales, an estimated 12,000 solar home systems are sold per year (Hansen U. *et al.,* 2015). According to (Mudoko, 2013) Uganda is endowed with favourable solar radiation from1, 825 kWh/m² to 2,500 kWh/m² per year. In Uganda, small solar applications are often used in rural electrification projects such as Photovoltaic solar home systems for lighting and charging small devices or in the form of solar thermal panels for water heating in urban areas. By 2015, Over 30,000 solar PV systems have already been installed in rural areas of Uganda (Mudoko S. N., 2013; RECP, 2015).

2.1.2. Mini-grid systems

The Energy for Rural Transformation (ERT) programme (part of the Rural Electrification Strategy and Plan) in Uganda, started back in 2002, now specifically focuses on increasing rural energy access from 1 to 10% through a combination of grid extension, mini-grids, and solar home system programmes. The 30 kW solar system was funded by Accenture Foundation, South Africa and the University of Notre Dame, USA under BOSCO Uganda's Project intervention Connectivity, Electricity and Education for Entrepreneurship (CE3) initiative. The technical development of the project was carried out by Power Gen a Nairobi-Kenya based Company (Solarplaza, 2017).

The rural electrification agency in Uganda has promoted the establishment of isolated mini-grids by using renewable energy technology including PV, for example by providing subsidies to investors (Hankins M. *et al.,* 2009). In 2012, the Rural Electrification Strategy Plan (RESP) (covering 2013-2022) also prioritises rural electrification through PV-powered mini-grids and has set a target of reaching 140,000 additional off-grid installations of solar PV systems and mini-grid distribution service connections in 2022 (GoU, "The Government of the Republic of Uganda, 2012). Some agreements with the East African Chamber of Commerce have been indicated that foreign investors are interested in developing mini-grids in Uganda particularly through solar PV technology (Brandt D., 2005; Hansen U. *et al.*, 2015).

2.1.3. On-grid systems

In 2007, the Renewable Energy Policy has been adopted by the Ugandan government and introduced the first phase of the Renewable Energy Feed-in tariff (REFIT) programme to encourage grid connected bagasse co-generation and hydropower plants. By 2011, a second phase of the REFIT programme was implemented and introduced a PV tariff rate at 0.362 USD/kWh. But, in 2012, this PV tariff was removed from the REFIT programme after a tariff revision due to the drop in PV system prices which makes PV technology to be competitive without subsidies (Tsagas I., 2013). According to (Africanews.com, 2016), Uganda has launched a 19 million U.S. dollar solar power plant in Soroti district in the North-eastern part of the country. This solar plant project is the largest in East Africa with the installed capacity of 10MW. The project will help to reduce power demand of country and it is expected to power 40,000 rural households in eastern part of Uganda (Solarplaza, 2017). The Soroti solar power plant is a private venture financed by a mix of debt and equity by FMO, a Dutch Development Bank, working with Emerging Africa Infrastructure Fund and is located 293 km east of Kampala. Electricity from the Soroti solar power plant would have cost $0.16 per kWh, but, end users will only pay 0.11 USD/kWh as a result of the intervention of donors (The EastAfrican.co.ke, 2016).

Figure 3: Soroti solar power plant (The EastAfrican.co.ke, 2016)

3. Rwanda

Rwanda is a small land-locked country of 26,338 km^2 in area with a population of 11,689,696 people (national census, 2012). It is a densely populated country in comparison to other African countries. In 2014, GDP was 643 USD/capita. (Republic of Rwanda, Ministry of infrastructure, 2015).Rwanda is a country endowed with plentiful natural resources such as methane gas, large river systems and high levels of solar irradiation. It has electricity generation capacity of 210.9 MW (in 2017) where the majority of this power comes from hydroelectric power plants (48%), thermal 32%, solar PV 5.7% and methane-to-power 14.3%. Rwanda locates just a few degrees south of the Equator makes it a good candidate for the development of solar PV plants. Based on current data, Rwanda has achieved 40.5% of electricity access rate which implies 11% off-grid and 29.5% on-grid (RDB, 2017).

3.1. Solar energy market in Rwanda

Rwanda is well benefited with solar energy, even during the months of the rainy seasons there is daily and sufficient sunshine as indicated in Figure 5, and the average daily global solar irradiation on the tilted surface is approximately 5.2 kWh/m^2 per day. The long term monthly average daily global irradiation range is from 4.8 kWh/ (m^2 day) (location Burera, month of May) to 5.8 kWh/ (m^2 day) (location Nyanza, month of July). This range indicates a good potential for solar energy development and it resulted in the 8.5 MW from solar power plant in Eastern Province of Rwanda in Rwamagana district. This plant was the first utility scale solar farm in Sub-Saharan Africa outside of South Africa (Jerusalem Post, 2015).

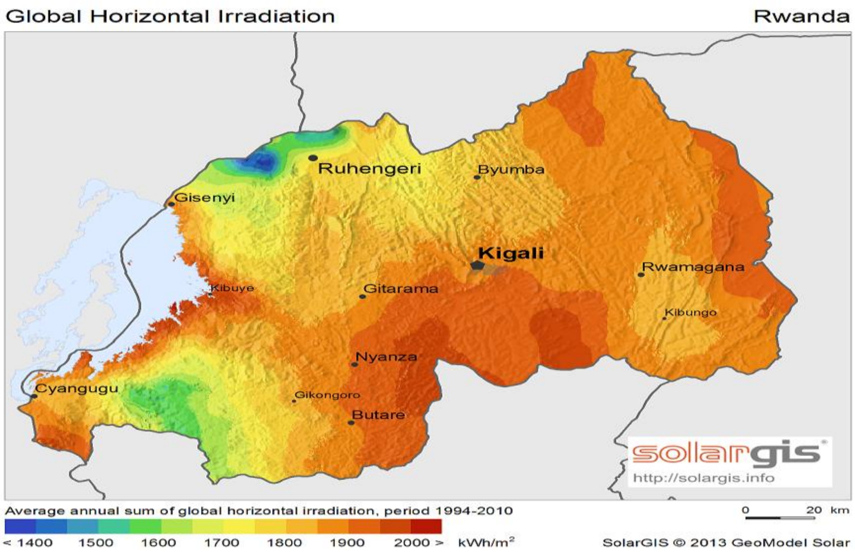

Figure 4: Global horizontal irradiation map of Rwanda

Due to the location of Rwanda, just a few degrees south of the Equator makes it a major candidate for the development of solar PV plants.

Figure 5. Monthly average daily global solar irradiance in Rwanda (Uwisengeyimana J.de D., 2017)

Table1. Total number of solar power plants and total capacity. (Republic of Rwanda, Ministry of infrastructure, 2015).

No	Plant Name	Installed Capacity (MW)
1	Jali	0.25
2	Ndera	0.16
3	Gigawatt/Rwamagana	8.5
Total		8.91

3.1.1. Off-grid systems

According to the Rwanda Ministry of Infrastructure, off-grid solar solutions are increasing in Rwanda. The Climate Investment Funds have allocated 50 million USD through the 'Scaling up Renewable Energy Program' to support the development of off-grid systems in Rwanda. The private sector is the major developer of off-grid solar solutions in Rwanda. The most popular private solar energy company of off-grid in Rwanda is MOBISOL. Rwanda has target to reach on 70% electrification that goal is outlined in the Rural Electrification Strategy; in fact, it is visioned to be met partially via off-grid solutions. It is expected that 22% of the electrified households will own smaller solar off-grid systems consisting of 4 light bulbs, a phone and radio charging. Currently, more than 100,000 Rwandans are using those safe solar systems (Solarplaza, 2017). In spite of ambitious of Rwandan government for electrification programs, more than 1 million households will still require off-grid electricity by 2020 and Survey results show that average cost of energy expenditures for off-grid household in Rwanda is around 500RWF or US$0.80 per week (Disch D. and Bronckaers J., 2012; Uwibambe J., 2017).

3.1.2. Mini-grid systems

Mini-grids are small distribution systems isolated from the national power system which includes a source of power generation such as hydro or solar. These grid systems are likely that they could play a role in energy provision in Rwanda but, given the large investment costs. The study of European Union (EU) for the cost of mini-grid in Rwanda estimates around $1500 per connection more than grid access (Republic of Rwanda, Ministry of Infrastructure, 2016). The government of Rwanda has committed to set up 100 solar PV mini-grids in different rural areas as a solution to reduce the effects of climate change. Furthermore, the world's largest off-grid battery system is coming to Rwanda by German commercial system manufacturer Tesvolt. This battery of 2.86 MWh of storage capacity will be connected to a 3.3 MW PV plant that is being developed by IdeemaSun Energy, as part of an agricultural project. The mini-grid project aims to supply energy during power cuts, which are very common in the East Africa region. There are other companies working towards rural electrification in Rwanda such as Energy 4 Impact and MeshPower. These companies have supplied 77,000 rural citizens with power solutions and creating 7,000 jobs (Solarplaza, 2017). In developed countries including Rwanda, mini-grids are progressively considered as an option to improve energy security, power quality and reliability, as well as to avoid power blackouts due to natural disasters (Kempener R. *et al.*, 2015).

3.1.3. On-grid systems

In February 2014, developer Gigawatt Global Coöperatief has closed on the $23.7 million financing of an 8.5 megawatt solar photovoltaic (PV) power plant with an international consortium of equity investors and debt providers. The electricity is being fed into the national grid under a 25 year power purchase agreement with Rwanda Energy Group Ltd (IPAD, 2015). In February 5th, 2015, Rwanda's first utility-scale solar PV plant was inaugurated. The project developed by GigaWatt Rwanda Limited. This solar plant is composed by 28,360 photovoltaic panels and produces 8.5 MW of grid-connected power to power 15,000 homes. The Gigawatt plant is the second large-scale solar field in East Africa, a field that is now providing approximately 6% of total electrical supply of Rwanda (Republic of Rwanda, Ministry of infrastructure, 2015). Goldsol II also projects developing a 10 MW solar PV plant in the Kayonza district, Eastern Province. In Southeastern of Rwanda, there is another project of 2.4 MW solar PV plant which is used to power eight secondary schools. It is funded partially by the European Union; the power plant is part of a larger program that aims to electrify schools in 27 districts across Rwanda (Solarplaza, 2017).

Figure 6: Gigawatt global at Rwamagana district (Republic of Rwanda, Ministry of infrastructure, 2015).

4. Challenges and Opportunities Facing Solar Energy Sector

4.1. Challenges

The major challenges in the solar energy sector are poor infrastructure for generation, transmission and distribution and low level of solar energy efficiency technology. Particularly, institutional framework of Uganda is characterised by several coordination failures, corruption in the public delivery system. These challenges impose constrains on planning and budgeting processes, leading to inefficient resource allocation and poor outcomes (RECP, 2015).

Other challenges include:

- Lack of strong legislative framework, practical policy, legal and regulatory environment for the private sector to be attracted to invest in solar energy sector.

- Cheap & availability of conventional energy sources.

- The high costs of investment in solar energy technologies make them uncompetitive in the market.

- Managing currency risks where there is a big depreciation compared to the US dollar.

- Community involvement and Tariff formation.

4.2. Opportunities

i) The global cost reduction in solar PV prices: Throughout the 1980s and 1990s the private solar market grew dynamically, as falling system prices and the introduction of smaller, more affordable solar power systems (Janosch O., 2011; GTZ, 2009a).The price of PV modules will be continuing to reduce due to prolonged support from international donors and favourable framework conditions provided by governments. Recently, the rapid decrease in the price of solar PV panels and rising oil prices made solar PV technology increasingly competitive with conventional technologies, such as diesel-fired generators, which are widely used throughout Africa (Hansen U. *et al.*, 2015).

ii) Availability of solar energy potential: Rwanda and Uganda are located just a few degrees of the Equator that makes them a prime candidate for the development of solar PV plants. Rwanda has monthly average daily global irradiation of 5.2 kWh/ (m^2 day) while Uganda has 5.1 kWh/m^2 per day, on a horizontal surface. This level of solar insolation is quite favorable, for the application of a number of solar technologies. In addition, solar energy is environment friendly and a source which can be found all over the world for free.

iii) Financial and technical support: In these two countries**,** international donors and investors are interested to promote solar energy use due to the geographic location of these countries. Furthermore, the government policies and programs are also used to promote the diffusion of solar PV market either direct or indirect. These are import duty and VAT exemptions for imported PV components, subsidies, favourable loan for solar PV suppliers and customers, and feed-in tariffs for investors of large-scale solar power plant.

5. CONCLUSIONS

- This paper has reviewed the development and current status of different solar energy systems in Rwanda and Uganda, and the support from donors, investors and governments to promote development of solar energy in these two countries.

- The paper finds that Rwanda has one of highest installed PV systems in East Africa where currently solar PV systems used to deliver electricity of 8.5MW to the national grid. While more than 177,000 solar home systems are installed in different institutions, school, health centers, public buildings and households. On the other hand, Uganda has the largest solar power plant in East Africa of installed capacity of 10MW. In Uganda, more than 30,000 solar home systems had been installed in different homes. The paper was found that, although Rwanda currently has the highest total installed solar PV systems especially solar home systems, Uganda is rapidly catching up.

- This peer review paper also identified that supports from international donors, government and international investors are used to promote solar PV diffusion from off-grid to mini-grids and to national grid-connection. In addition, the import duty and VAT exemptions, subsidies and feed in-tariff are instruments government used to attract investors.

- Finally, the paper discusses the challenges and opportunities facing Rwanda and Uganda in development of solar energy. The major challenges in the solar energy sector are Lack of strong legislative framework, practical policy and monetary risks. Rwanda and Uganda have some opportunities; global cost reduction in solar PV prices and availability of high solar potential with average daily irradiation of 5.2 kWh/m^2 per day and 5.1 kWh/m^2 per day in Rwanda and Uganda respectively.

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